AD-A190 228

NAPPING AND HUMAN FUNCTIONING DURING PROLONGED WORK

Paul Naitoh*
Robert G. Angus**

*Naval Health Research Center
P. O. Box 85122
San Diego, California 92138-9174

**Defence and Civil Institute of Environmental Medicine
1133 Sheppard Avenue West
Downsview, Ontario
Canada M3M 3B9

To expedite communication of this research, this is a preprint of a paper submitted to the book, "Napping: Biological, Psychological, and Medical Aspects," (D. F. Dinges and R. Broughton, Eds.), Raven Press.

Report No. 87-21, supported by the Naval Medical Research and Development Command, Bethesda, Maryland, Department of the Navy, under research Work Unit No. 3M463764B995.AB.087-6. The views presented in this paper are those of the authors and do not reflect the official policy or position of the Department of the Navy, the Department of Defense, nor the U. S. Government. The authors gratefully acknowledge the editorial assistance of Tamsin Kelly, M.D.

CONTENTS

SUMMARY

The need for research and recommendations about naps (short sleeps taken to replace regular nocturnal sleep) in order to keep men and women productive during prolonged work periods is discussed in the context of sleep management. Sleep management shows how to maintain human functioning by pre-planned napping during a prolonged work period. The literature on napping was reviewed to analyze the relative power of the four factors of napping, (i.e., nap length, nap time, length of prior sleep loss, and nap infrastructure), in determining a nap's effectiveness to maintain human performance competence. Some of the significant information gaps revealed in the nap literature are currently being filled by nap studies which are conducted at the Defence and Civil Institute of Environmental Medicine (DCIEM) and, independently, at the Naval Health Research Center (NHRC). The studies in these research centers are described, showing that a nap is invariably effective in maintaining performance and moods when a nap is taken prophylactically before degradation of performance and mood due to sleep loss and fatigue. These studies also confirmed that a nap will help to restore degraded human functioning. The most critical finding is in confirming that a brief period of time immediately after awakening from a nap is characterized by paradoxical increases in performance/mood deterioration, that is "sleep inertia." Men and women need some finite time in fully awakening from sleep, especially from an insufficiently long nap taken after severe sleep loss. Because of after-effects of sleep inertia, naps appear not to provide refreshing recuperation from fatigue of a prolonged work period. Critical evaluation of nap literature and recent studies on performance and mood during prolonged work periods has revealed several unresolved questions related to sleep management. One of the most significant questions is how short a nap can be before it loses its recuperative power. An extremely short nap of one minute or less (ultra-short naps) has been found not to restore human functioning. Since the short and ultra-short naps are mostly the types of sleep which will be available for men and women during a period of prolonged work, there seems to be the need to understand the recuperative power of short or ultra-short sleep. The nature of ultra-short sleep over performance and mood is discussed on the databases of "short day" experiments and long distance yacht racing. Research studies

on prophylactic use of ultra-short sleep in a prolonged work period are proposed to provide the key information on sleep management.

1. INTRODUCTION

This chapter will focus on sleep management and the usefulness of napping for maintaining and recovering function during and after prolonged work. Sleep management is the determination of how to satisfy sleep needs of people who work under demanding conditions. Sleep management concepts have been around for over 50 years (44). Sleep logistics is a military application of sleep management, which includes balancing the cost of losing manpower during sleep against the gains of increased alertness and competence (30, 68). Napping is defined here as short sleep periods (less than 50% of an individual's average nocturnal sleep) during the day or night, which are used to replace rather than supplement normal nocturnal sleep. The extent to which partial or total sleep loss and disturbed sleep affect mood and performance will not be fully discussed. Readers are referred to many reviews that are already available on this topic (38, 42, 63, 92, 98).

2. REVIEW OF SLEEP LITERATURE

2.1 Partial Sleep Deprivation Studies

The first partial sleep deprivation study was conducted by May Smith (76) on herself. She reduced her sleep from eight hours a night to 5.5, 3.5, and 1.5 hours over three consecutive nights. The immediate effect was improvement in task performance. Decreased task performance occurred only after a recovery sleep. Smith suggested that usually untapped reserves were being employed and exhausted during sleep deprivation.

Some other partial sleep deprivation studies also showed little decrement in performance (22, 73, 87, 88). However, this may relate to the use of insensitive tests (83). Wilkinson (93) suggested that undemanding tasks of short duration may be insensitive to partial sleep loss. The loss of one night of sleep usually has no effect on the first five minutes of tasks but produces clear impairment after 15 to 45 minutes of performance (91, 92).

More sensitive tests have shown impairment after partial sleep deprivation (27, 81, 83, 93, 95). Wilkinson et al. (95), allowed subjects 0, 1, 2, 3, 5, or 7.5 hours of sleep per night on two consecutive nights. Following the first night, subjects who were allowed two or less hours of sleep showed impaired performance on a 1 hour test of vigilance and a test of addition. Those with three hours of sleep maintained baseline performance through the following day. However, after the second night, even those subjects who had slept for 5 hours each night showed impaired performance.

In a subsequent study (27) subjects were permitted 4, 6, or 7.5 hours of sleep per night over four consecutive nights. The subjects permitted 4 hours of sleep showed impaired performance on both vigilance and addition tasks but not on a digit span memory task. A recent study showed that performance on a 20 minute unprepared simple reaction time task deteriorated after a night with 4 hours of sleep (83). Thus, more than 4 hours of nocturnal sleep is required to maintain performance on some tasks but not others.

Friedmann et al. (22) had subjects gradually reduce their amount of sleep. Subjects could not maintain mood and task performance if they reduced their sleep to less than 4-5 hours per day. This "obligatory sleep" length was the same for long sleepers (usually slept 9 hours per night) as for short sleepers (habitually slept 6 hours). Thus, long sleepers could reduce their sleep by 4 hours while short sleepers could only reduce by 1 hour.

It has also been reported (39) that long sleepers do not need additional sleep beyond their habitual nightly sleep following 36 hours of continuous wakefulness, while normal and short sleepers increase their usual sleep lengths by 25% and 33% respectively. This suggests that long sleepers are getting sleep beyond obligatory sleep, while short sleepers are getting obligatory sleep only.

Mullaney et al. (62) required subjects to work at four tasks repeated every 10 minutes for 42 hours. This high intensity protocol produced serious performance deterioration and psychological changes after 18 hours (at about 2300h). This is earlier than has generally been reported in sleep-loss studies (42). However, this study may be limited by the strong element of monotony which enhances sleep loss effects (92).

Partial sleep deprivation studies have also been conducted outside laboratory environments. Haslam (33) conducted a 9 day long tactical defensive exercise in the field. Soldiers were allowed 0, 1.5, or 3 hours of sleep each night, starting at 0230h. A 90 minute performance test battery consisting of many short cognitive tests was used to evaluate performance each morning. All 22 subjects in the no-sleep condition withdrew from the exercise after the fourth night without sleep, while 12 of 23 in the 1.5

hour sleep group completed the 9 day exercise as did 20 of 22 in the 3 hour sleep group. However, the survivors in the 1.5 hour sleep group were considered by military observers to be combat effective for 6 days, while all survivors in the 3 hour sleep group were combat effective for 9 days.

Another field study (1) showed that tank crews were able to perform all necessary military maneuvers without serious decrements during 48 hours without sleep. An earlier laboratory study of a simulated driving task by the same research agency (19) had shown significant deterioration in driving performance after 48 hours without sleep.

Close examination of these field studies suggests that the performance measures used were sensitive to large deteriorations in the performance of military actions but not to more subtle, but potentially serious, degradations. The discrepancies between the laboratory and field results illustrate the dangers of extrapolating laboratory results to field conditions and the limitations of field research.

2.2 Nap Studies

Research into partial sleep deprivation and performance has looked primarily at the effects of limiting nocturnal sleep. The beneficial effects of daytime naps, both in preventing mood and performance deterioration and in relieving it once it has occurred, are less well understood. The studies discussed in section 2.1 involved a single continuous block of sleep at night. Many sleep researchers agree a minimum of 4-5 hours sleep must be taken in an uninterrupted period to prevent impaired performance. The continuity theory of sleep postulates that continuous sleep has greater recuperative power. If sleep occurs in short pieces over a 24 hour period, it is much less effective, even if total sleep time is the same. The sleep of patients with sleep disorders such as sleep apnea (26), narcolepsy-cataplexy (12, 61), and periodic movements in sleep (54) is fragmented These patients have increased sleepiness and behavioral deficits during the daytime. However, this may relate more to their underlying pathology than to a general lack of benefit from naps.

Using normal subjects Hartley (28) compared task performance of a group who had a single 4-hour block of sleep with a group who had three 80-minute sleep periods starting at 2310h, 0530h, and 1225h. Performance on a vigilance task administered once a day at 2100h was better after the distributed sleep than following continuous sleep. However, there was a shorter time between waking and testing in the distributed nap group (7.75 vs 16.5 hours).

Mullaney et al. (62) looked at sleep deprivation effects on a tracking task, a visual pattern memory task, and an addition task (all 3 minutes long). All subjects had 5 hours of sleep immediately before the start of the study. The study lasted from 0500h of the first day to 2300h the next day. One group of subjects was allowed a 1 hour sleep period every 7 hours (6 hours total). Another group was allowed to sleep for 6 hours continuously (from 2300h to 0500h). There was only a nonsignificant trend for subjects who had continuous sleep to perform better during the last half of the 42 hour study than those who had 1-hour sleep periods. This paper does not report the sleep efficiency (actual time asleep as a percent of the time available) in the two conditions.

In a field trial Haslam (34) compared the effects of a 4 hour early morning nap (0200h-0600h) with four 1-hour naps taken at 0500h-0600h, 1100h-1200h, 1700h-1800h, and 2300h-2400h. Subjects were awake for 23 hours before the 4 hour sleep or the first nap. Performance tests included 15 minute cancellation, addition, and logical reasoning tasks, separated by one minute breaks. Sleep log data showed that the subjects with four 1 hour naps slept less than those in the 4 hour continuous sleep group. Despite this, there were no significant differences in task performance.

Webb (84, 85) observed performance over 72 hours on many tests and measures of mood in groups which got: two 2-hour naps (0800h-1000h) the mornings of days 2 and 3; two 2-hour midnight naps (2200h-2400h) after days 1 and 2; or one 4-hour midnight nap (2000h-2400h) after day 2. Looking at the last test session (2400h-0600h on the third day), he found that only 4 of 13 sleep deprivation sensitive measures showed any differences between the groups, and these differences were inconsistent. One measure favored the evening nap group, one the morning nap, one the 4 hour nap, and one the two 2 hour naps.

Dinges et al. (17, 18), Nicholson et al. (69), Haslam (34), and Taub et al. (82) have shown that naps taken prior to accumulating sleep loss can prevent declines in performance and mood. This suggests that the benefits of sleep can be "stored" and dispensed as necessary.

Webb (84) reviewed six factors thought to be important (67) when determining the minimal amount of sleep necessary to maintain human performance.

They are: (1) the length of sleep deprivation, (2) the length of the nap period, (3) the circadian placement of the nap, (4) the elapsed time between the end of the nap period and the beginning of post-nap performance, (5) the circadian time of task performance, and (6) the performance task. The literature related to the first four factors will be reviewed.

2.2.1 Length of Prior Sleep Loss and Length of Nap Periods

Woodward and Nelson (100) suggested that increased amounts of sleep are required for recovery from the effects of increased periods without sleep (see also 44). About 8 hours of sleep is needed after a normal waking day of 16 hours. They speculated that: about 12 hours of sleep would be required following 24 hours of continuous work; 12-14 hour of sleep after 36-48 hours; and 2-3 days of sleep following 72 hours of work.

Morgan and Coates (59) found that, after 36 hours of work, 2 or 3 hours of rest restored performance to about 60% of baseline, 4 hours of rest restored 70%, and 12 hours restored 100%. Four hours of rest after 44 hours of work recovered only 40% of baseline performance. The rest periods in this study included meals and other activities as well as sleep, and the actual sleep duration was not stated.

Wilkinson (94) found that, following one night of sleep loss, vigilance and addition performance recovered to acceptable levels after 2 hours of sleep but, following two nights of sleep loss, 5 hours was needed. Rosa, Bonnet, and Warm (72) found that after 48 hours of continuous work, 4 hours of sleep was required to return reaction times to baseline, while after 64 hours of sleep loss, a full 8 hours of recovery sleep was necessary.

2.2.2 Circadian Placement of the Nap

When a nap is taken during the day may be important. The circadian cycle is defined by the 24 hour rhythm of body core temperature and there is an associated cycle in level of alertness. Studies have found that naps at various times of day or night are beneficial for maintenance or recovery of performance, but, often, more benefit is gained from afternoon and evening naps than from morning naps (17, 23, 50, 66, 80). Naitoh (66) showed that a 2 hour nap taken near the circadian nadir (trough nap) in alertness (0400h-0600h) after 45 hours awake had less recuperative power than a nap taken during the rising circadian phase (1200h-1400h) after 53 hours awake (peak nap). Dinges et al. (17) studied subjects during a three day period of almost continuous work. Subjects were allowed 2 hour naps at one of two time periods. Peak naps were from 1500h-1700h, and trough naps were from 0300h-0500h. Reaction times immediately upon awakening did not differ, but performance on a subtraction task indicated greater cognitive deficits after trough naps. Recently, Lavie and Weler (50) showed that there was less post-nap sleepiness and mood deterioration after a 2 hour nap taken between 1500h-1700h than one taken between 1900h-2100h.

Others have found that 2 hour naps had similar benefits on a simple reaction time task whether they occurred at the circadian peak or trough (18). Webb (84) also found no evidence that morning naps were more beneficial than afternoon naps. Gillberg and Akerstadt (24, 25) found no difference in morning performance between a 1 hour nap taken at either 2100h or 0430h, but their results may be confounded by large differences in time from waking to testing between the conditions.

2.2.3 Sleep Inertia and Nap Infrastructure

The term sleep inertia refers to the phenomenon of inferior task performance occurring immediately after awakening from sleep. This was documented in an early study by Langdon and Hartman (48). Reported durations of sleep inertia have varied greatly. Tilley and Wilkinson (83) observed a marked residual awakening effect, although behavioral testing was delayed for half an hour after awakening. Earlier, Wilkinson and Stretton (97) speculated that the immediate effect of sudden awakening would dissipate in four minutes. They based this on performance at night which was quite stable when the tests were given 4 minutes post sudden awakening. The decrement measured when subjects were awakened during the night was explained as a circadian effect on performance and not as persisting sleep inertia, but it is unclear how one differentiates sleep inertia from circadian influences on performance.

Taub (80) found that sleep inertia was usually brief when subjects were not deprived of sleep for a long period of time but could sometimes be seen for as long as two hours post sleep. Labuc provided practical suggestions to shorten sleep inertia (45, 46, 47). Naitoh suggests that sleep inertia is most severe around the circadian nadir and least severe near the circadian peak. At times the recuperative benefits of nap sleep might be masked by sleep inertia.

The infrastructure of a nap refers to the organization of sleep stages within the nap. The first 4 hours of a normal 8 hour sleep period is predominantly Slow Wave Sleep (SWS, stages 3 and 4 combined) while the second 4 hours is predominantly Rapid Eye Movement Sleep (REM) and stage 2 sleep. The fact that the minimum nocturnal sleep duration for performance maintenance is 4-5 hours (22, 39) suggests that SWS may play an important role. However, nap infrastructure is not a miniature version of the pattern seen during the normal 8 hours of nocturnal sleep. It varies with nap duration, time-of-day, and length of prior wakefulness. Up to a point, the shorter the nap, the higher the percentage of SWS. Morning naps contain a higher percentage of REM sleep than naps at any other time of day. The longer the preceding sleep loss, the greater the percentage of SWS.

Some researchers have found that certain sleep stages contribute more to maintenance and recovery of human function than others. Dinges et al. (16, 17) measured the effects of 2 hour naps following 6, 18, 30, 42, or 52 hours of sleep loss. They found that subjects with more SWS during the nap performed worse on a descending subtraction task given immediately after sudden awakening. Bonnet (10) found that the total amount of SWS plus REM sleep during a night of disrupted sleep predicted scores on addition, vigilance, and simple reaction time tests given on the following morning. However, experimental findings obtained at the NHRC indicate that sleep stages 2, 3, 4 and REM are equally recuperative (43, 53, 65).

There is less controversy over the effects of the sleep stage from which subjects are awakened. Webb and Agnew (86) studied afternoon naps of non-sleep deprived subjects. They found that reaction times immediately after awakening were slowest following stage 4 sleep. Feltin and Broughton (20) reported that average decision time was prolonged after arousal from SWS but not from REM sleep. Fort and Mills (21) found inferior performances on a cancellation task immediately after arousal from stage 4 sleep, with improved performances following arousal from stage 2 sleep. Dinges et al. (16) used non-sleep deprived subjects who were awakened from sleep by a telephone bell. Reaction times were longest for subjects who were awakened from stage 4 sleep. Bonnet (8) found that short-term as well as long-term memory was worse for information learned after arousal from stage 4 sleep than from stage 2 sleep. Other studies have shown that reaction time (17, 74, 75), vigilance (21), sensory discrimination threshold (74, 75), clock reversal (74), and arithmetic problem solving (75) are all worse shortly after awakening from SWS than from REM or stage 2 sleep.

2.3 Ultrashort Sleep Studies

Ultrashort sleep has been defined as sleep periods less than two hours in duration (Personal Communication, Roger Broughton). Laboratory studies on ultrashort sleep include "short day" experiments and disrupted sleep studies (10, 13, 14, 49, 52, 55, 60, 89).

An early short day study was conducted by Weitzman, et. al. (89). They imposed a sleep-wake schedule of 1 hour sleep and 2 hours awake (i.e., a 3 hour day) for 10 calendar days. The results showed that the subjects reduced total sleep from 7 hours/24 hours during the baseline sleep to about 4.5 hours/24 hours even though they were given opportunities for 8 hours each 24 hour period. Most of this decrease came out of REM sleep, while the least change was observed in SWS. Sleep efficiency was only 56%. No performance and mood data were available in this report.

Carskadon and Dement (13) imposed a sleep-wake schedule of 30 minutes sleep and 60 minutes awake (90 minute day) for 5.3 calendar days. Total sleep time was reduced from about 8 hours to 5 hours per day. Sleepiness, as measured by the Stanford Sleepiness Scale, increased significantly during the first day of the study but decreased almost to the baseline over the next four days.

Lubin et al. (52) reported on the effects of a sleep-wake schedule of 60-160 minutes followed for 40 hours. The authors stated that the purpose of their study was to determine whether prophylactic naps prevented sleep loss decrements in performance when subjects were deprived of normal nocturnal sleep. Total sleep time was reduced to 6.1 hours/24 hours. The napping subjects showed significant impairment in short-term memory and sleepiness only near the end of the 40 hour period.

Moses et al. (60) reported on sleep efficiency and percent sleep stages in these subjects along with those of Weitzman et al. (89) and Carskadon and Dement (13). The ultrashort sleep pattern decreased sleep efficiency in all three studies. Sleep efficiency fell from greater than 90% at baseline to about 50%. Percentages of stage 1 and SWS increased, and percentages of stage 2 and REM decreased. During recovery, proportions of SWS, REM, and stage 2 were similar to baseline.

Bonnet (10) reported an experiment lasting two consecutive nights, in which groups of subjects were awakened repeatedly: 1 minute after each onset of stage 2 or REM; 10 minutes after each onset; or 2.5 hours after each onset. Another group remained awake for the full 64 hours of the study. Polygraphic sleep recordings were obtained and subjects completed a 30 minute Wilkinson Addition test, a 30 minute Wilkinson vigilance test, and a 10 minute simple reaction time test each morning.

As expected, the total sleep loss condition produced greatest performance decrements. The 1 minute sleep condition caused the next greatest decrement, with a level of performance the morning after the second night similar to that of the totally sleep deprived subjects. The 10 minute sleep subjects did somewhat better, and the 2.5 hour sleep condition produced the least decrement.

Polygraphic analysis showed that subjects in the 1 minute condition slept 4-4.5 hours out of an available 7 hours, with a sleep efficiency of 67% and 62% for the first and second nights respectively. SWS and REM sleep were essentially eliminated. The subjects in the 10 minute condition slept about 6 hours, and those under the 2.5 hour condition slept 5-5.5 hours. Both had small reductions in stages REM and SWS. All three groups showed a significant rebound in SWS during the first recovery night and a significant rebound in REM sleep during the second night.

MaGee, Harsh, and Badia (55) also showed a large reduction in total sleep time, virtual elimination of SWS, and a great reduction of REM in subjects allowed only 1 minute sleep periods. This was reflected in increased daytime sleepiness as measured by the multiple sleep latency test. A 4 minute sleep condition showed only a small reduction in SWS, no change in REM, and no increase in daytime sleepiness. Other studies (8, 9) have shown that fragmentation of nocturnal sleep produces behavior impairment.

A field database on ultrashort sleep has been derived from Stampi's observations on yachtsmen on solo yacht racing (78, 79). The average total sleep taken was 6.3 hours per 24 hours. Most (68%) of the solo yachtsmen sustained mean sleep lengths of 10-20 minutes. Stampi found significant correlations between mean sleep length and performance: sailors with the shortest sleep episodes finished highest in the standings.

2.4 Drugs as an Alternative to Ultra-Short Sleep

Because of current limitations in predicting how a given sleep pattern will benefit individuals, some researchers recommend the use of both sedatives and stimulants in prolonged work conditions to create a proper level of activation. Seidel et al. (77) showed that benzodiazepines might be useful in overcoming rapidly phase-adjusting sleepiness. However, the use of drugs for maintaining performance has many problems. Required dose varies, as does rapidity and duration of effects. There may be a hang-over, side-effects, or adverse interactions between drugs or between stressors and drugs. Tolerance or dependence may develop after repeated drug use. A serious drawback is that, once taken, little can be done to reverse their course of action.

Another situation where the use of hypnotics and stimulants has been suggested is for handling jet lag. Since we usually accumulate a considerable amount of sleep loss before departure, people are often advised to sleep as much as possible when traveling to distant destinations to reduce sleep debt. Because sleeping during flight is usually difficult, a short-acting hypnotic may be recommended. However, sleep loss is only a part of jet lag syndrome.

Moore-Ede, Sulzman, and Fuller (56) described a two-oscillators hypothesis. One oscillator controls core temperature related circadian rhythm and another oscillator controls sleep-wake rhythms. Circadian rhythms in performance appear to go along with the body temperature. Sleep-wake patterns can be changed at any time, but the temperature cycle may take several days to adjust.

If an individual sleeps well while traveling, he may not be sleepy on arrival but his performance will still be synchronized to the home base. The break in the natural coupling between the two oscillators can be dangerous since increased sleepiness usually prevents us from working near the trough of performance efficiency. Perhaps a substance can be found which shifts temperature and performance cycles more quickly.

There have been recent efforts to use natural hypnotic substances, such as L-tryptophan, because of the presumption that natural substances are safe. However, L-tryptophan does not naturally occur in doses large enough to achieve hypnotic effects, and the administrations of a large dose of L-tryptophan alone, without other amino-acids, is not necessarily safe.

On the other hand, some drugs produce predictable behavioral changes which are very useful for handling certain situations. Caffeine is often used to overcome sleepiness in prolonged work. Sleeping pills are used to overcome situational insomnia. Research on drugs and natural substances should be continued to find optimal ways to use them. However, the first and best solution is to work out sleep-wake cycles and appropriate nap schedules. Only when such schedules fail should the use of drugs be considered.

3.0 NEW INFORMATION ON NAPPING

3.1 Defence and Civil Institute of Environmental Medicine (DCIEM) Research

Background

As discussed, there are problems with generalizing laboratory studies of prolonged work periods to actual command and control (C2) operations. Performance degradation is highly dependent upon the types of tasks to be performed (97). The tasks used in laboratory studies are often not representative of operational tasks. Testing is usually infrequent, varying from every hour or two (3, 57, 58) to only once per day (31, 70). Abilities may thus be overestimated based on short term high-energy expenditures that could not be maintained for more prolonged periods (30, 40, 58, 64).

Short tests may be insensitive to sleep loss effects. Intense or long tests are more sensitive, but repetitive situations used in the laboratory may cause exaggerated decrements secondary to monotony. True operational situations are usually much more complex than laboratory testing. The interactions of sleep deprivation with other environmental or situational stressors is poorly understood (41). DCIEM's research program was designed to address some of the above limitations and to determine performance limits and biological changes with sleep loss in command and control (C2) personnel.

Experimental Environment

The DCIEM research environment provides a continuous high-demand battery of sensitive cognitive measures of meaningful C2 type performance. The laboratory is self-contained and can accommodate personnel for extended periods. Subjects work in individual test rooms. Closed-circuit television is used to monitor the subjects from the experimenters' control area, and slave monitors display the information on each subject's terminal screen. Continuous EEG, ECG, and other physiological responses are recorded on ambulatory cassette recorders. A computer presents the stimuli, collects the responses, and stores the data.

Experimental Design and Tasks

Both male and female university students have been used as subjects. Military subjects have included young enlisted men, young officers, and older (35-40 years) commissioned and noncommissioned officers. On day 1 of a typical five day experiment, subjects are briefed on the scenario and the military concepts and terminology are explained. Subjects are trained extensively on all tasks. In the evening they relax, are prepared for physiological recordings, and are allowed to sleep for 8 hours. They are awakened between 0600h-0800h the next day, and the scenario begins approximately an hour later.

This scenario simulates a brigade level command-post in which subjects assume the role of duty operations officers who monitor a communications network, update tactical maps, read messages, and answer questions. The messages require subjects to decode the resource state and identify the locations of various units (using the map grid references), describe the units' activities (current or intended), select the most appropriate unit for specific tasks, calculate equipment resources, and estimate travel distances and times of arrival. Most questions require short phrases to be typed on computer keyboards. Some require the scenario map to be up-dated. Others request that summaries be hand-written and manually filed. Previously processed messages cannot be retrieved from the computer, so the manually filed information is necessary for answering questions in later messages.

A variety of short cognitive tests which have been found to be as sensitive to sleep loss effects as longer duration tasks (36) are incorporated into these experiments, including: a variant of the four-choice Serial Reaction Time task described by Wilkinson and Houghton (96); an Encoding/Decode task similar to that reported by Haslam (34); a Continuous Subtraction task adapted from Cook, Cohen, and Orne (15); and a Logical Reasoning task devised by Baddeley (7). Some of these tasks were slightly adapted for the military scenario. The following self-report measures are also collected: the Stanford Sleepiness Scale (37); the School of Aerospace Medicine (SAM) Subjective Fatigue Checklist (29); and the NHRC Mood Scale (42). More detailed information about tasks and comparisons with results from other studies are given elsewhere (4, 5, 6, 35, 36).

After 64 hours of performing these tasks with sleep deprivation, the subjects have an 8 hour recovery sleep (during the same hours as the baseline sleep). The next morning there is 6 hours of testing to determine degree of recovery.

The experiments follow a general design in which several 6 hour blocks of identical cognitive tasks are presented. Only the content of the military messages changes. Figure 1 illustrates the design of a study investigating the effects of a nap between 2200h-2400h, after 40 hours of sleep loss. Figure 2 shows the activities within the eleven task blocks. In this experiment there were three 2-hour work sessions per block separated by 15 minute breaks, except in block 7 where a nap was substituted for the second work session. The experimental tasks range in duration from 5-15 minutes. A 15-minute "Scales and Battery" package, including the previously described cognitive tasks, occurs at the beginning of each hour during a work session.

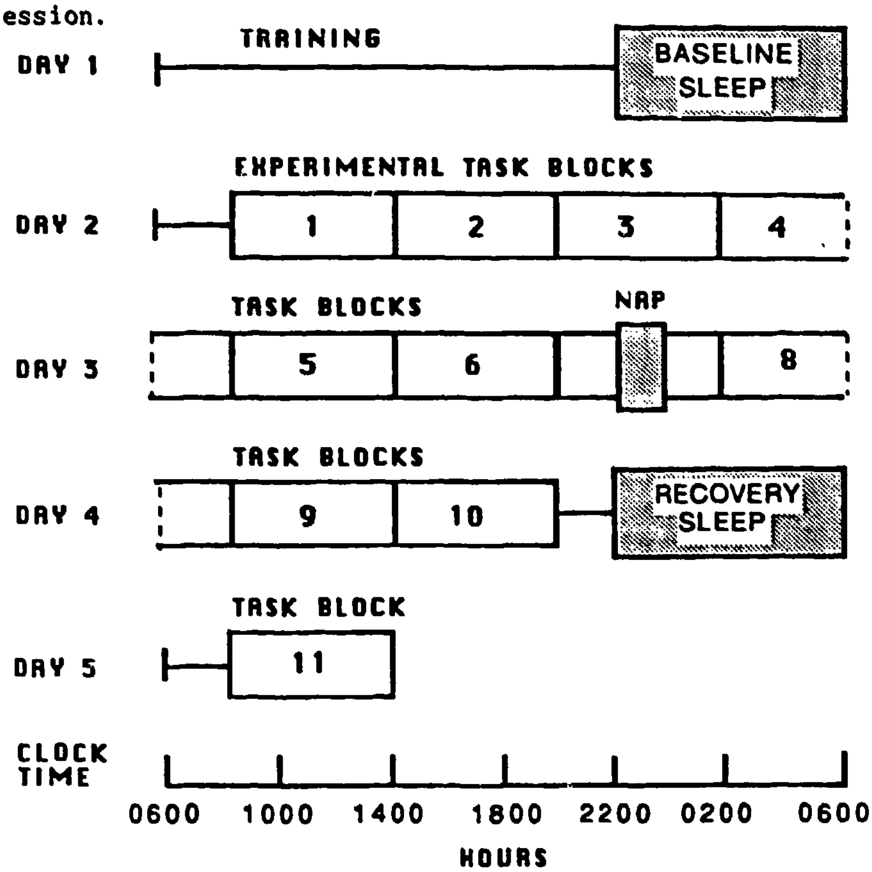

Figure 1: Outline of design for an experiment investigating the effects of a 2-hour nap between 2200h-2400h.

6 - HOUR TASK BLOCK

START TIME (Real)	START TIME (Elapsed)	TASKS	
08:00	00:00	Scales & Battery	
08:15	00:15	Decode (Normal)	
08:20	00:20	Messages	
08:30	00:30	Decode (Motivated)	
08:35	00:35	Messages	
08:45	00:45	Scales & Battery	SESSION 1
09:00	01:00	Decode (Group)	
09:05	01:05	Syllogisms	
09:20	01:20	Messages	
09:30	01:30	Decode (Normal)	
09:35	01:35	Missile Defence	
09:40	01:40	**** Break ****	
10:00	02:00	Scales & Battery	
10:15	02:15	Serial	
10:25	02:25	Messages	
10:35	02:35	Subtraction	SESSION 2
10:40	02:40	Messages	
10:55	02:55	Scales & Battery	
11:10	03:10	Messages	
11:20	03:20	Logical Reasoning	
11:30	03:30	Missile Defence	
11:35	03:35	**** Break ****	
12:00	04:00	Scales & Battery	
12:25	04:15	Memory (Training)	
12:35	04:25	Messages	
12:35	04:35	Digit Span	SESSION 3
12:45	04:45	Messages	
12:55	04:55	Scales & Battery	
13:10	05:10	Messages	
13:20	05:20	Plotting & Memory (Recall)	
13:30	05:30	Missile Defence	
13:35	05:35	**** Break ****	

Figure 2: Experimental activities and their temporal occurrence during a typical 6-hour task block.

Experimental Results

DCIEM studies have found greater decrements in performance following sleep loss combined with intensive mental work than previous studies with less emphasis on cognitive demands. Decrements of greater than 30% occurred following 18 hours on duty, with unacceptable performance (greater than 60% decrements) occurring by 42 hours. Physical fitness level appeared to be unrelated to degree of degradation in cognitive function. Exercising one-third of the time at approximately 35% of maximal oxygen uptake level did not affect cognitive functioning nor did the injection of brief (30 min) periods of strenuous exercise. Reducing the cognitive workload during the day did not alter the performance impairment during the subsequent night.

Previous continuous work experiments had shown that performance was reduced to less than 40% of baseline following a second night of sleep loss. In the study outlined in Figure 1, subjects worked continuously for 40 hours and then received a 2 hour nap (2200h-0001h) prior to the expected decline in performance. Subjects did not expect the nap and were not informed what its duration would be. Figure 3 shows performance scores obtained on a Serial Reaction Time task during the 6 hours before and 4 hours following the 2 hour nap. The worst performance occurred immediately after awakening

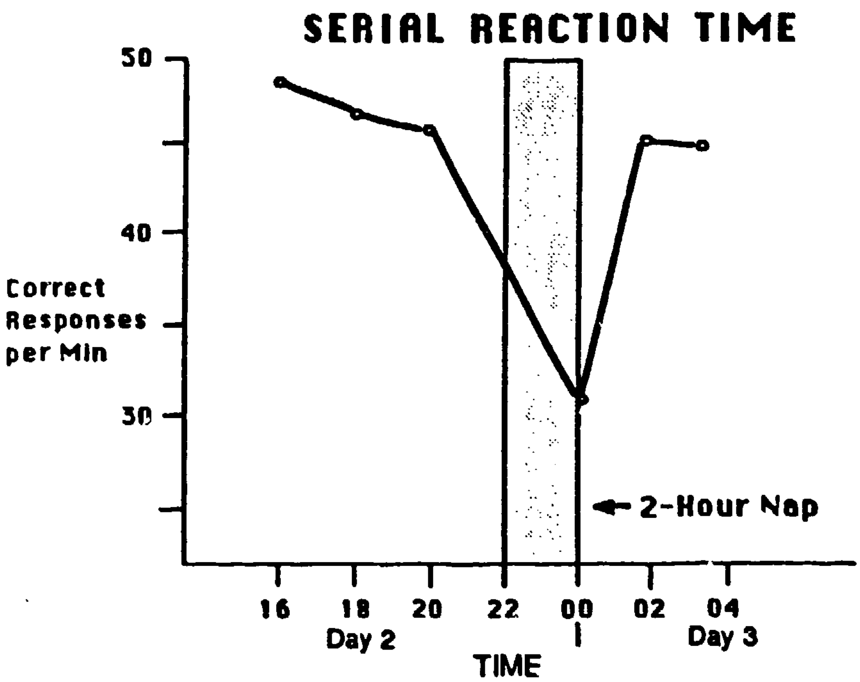

Figure 3: Mean number of correct responses on a 2-minute Serial Reaction Time task. Data were collected "After Rest" breaks at three places prior to a nap, immediately following the nap and following the next two rest breaks. The nap occurred after 40 hours of sleep loss between 2200h-2400h.

from the nap (sleep inertia). Performance recovered up to the level observed after one night of sleep deprivation, 2-4 hours after the nap. That is, the 2 hour midnight nap was able to maintain performance during the second night without sleep at the pre-midnight level but was not long enough to return subjects to baseline level. These results are typical of most of the tasks studied.

A study similar to the one just discussed explored the recuperative power of a 2 hour nap, the ability to revive already degraded performance. In this study the nap (again unexpected) was placed at the trough (0400h-0600h) of the circadian cycle after about 46 hours of wakefulness, several hours after the usual large decline in performance observed during the second night of sleep loss. Figure 4 shows the results from a logical reasoning task. Again, task performance was worst just after awakening and subsequently improved to the level present prior to the second night of sleep loss.

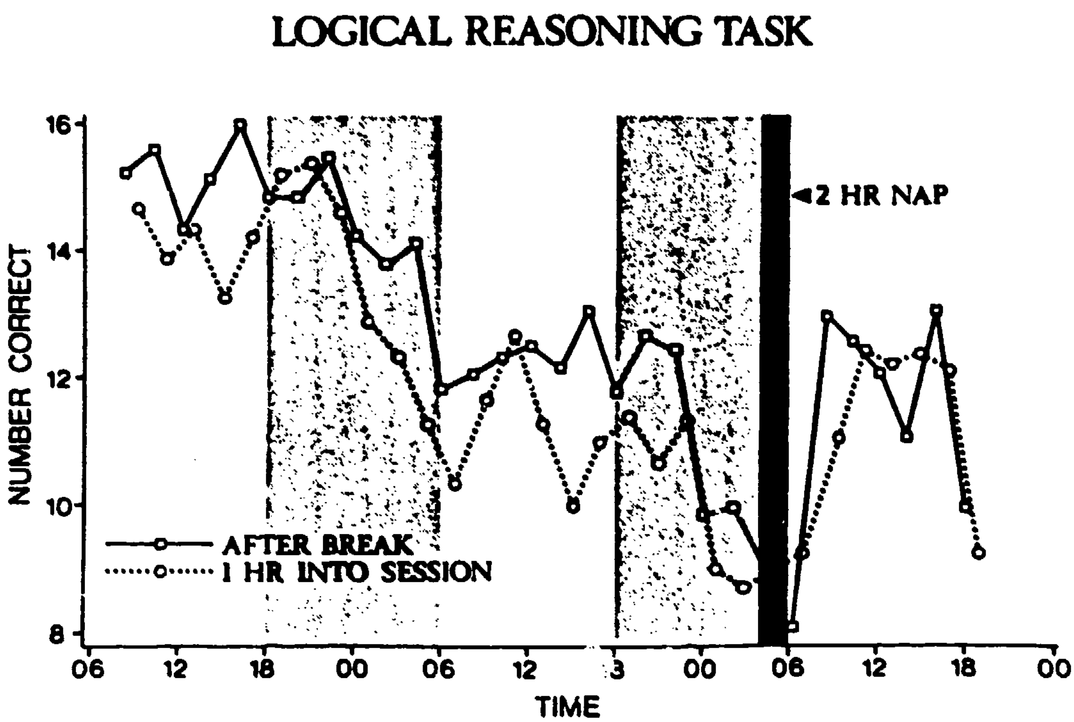

Figure 4: Number of correct responses on a 2-minute Logical Reasoning task given every hour. The results are divided into trials occurring after a 15-minute break bad trials occurring 1-hour into a 2-hour work session.

(Gray bands signify night). Note the nap between 0400h-0600h (after 46 hours of wakefulness) and its recuperative effect on performance.

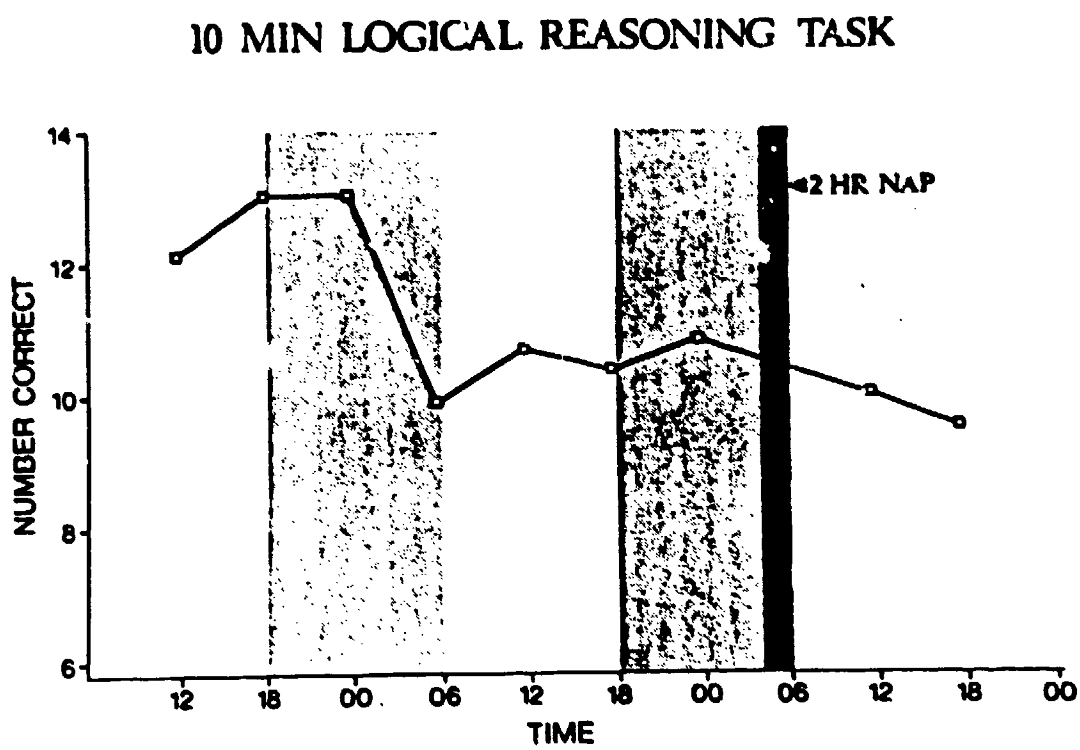

Figure 5: Number of correct responses on a 10-minute Logical Reasoning task given once every 6 hours during a 60-hour sleep deprivation experiment.

A nap occurred between 0400h-0600h after 46 hours of wakefulness.

Sleep inertia can be missed if performance is not tested soon after a nap. The Logical Reasoning scores just discussed show improvements well within one hour. Figure 5 shows the same data as it would appear with infrequent testing or with an analysis which averages the data over a large time interval. The relevance of sleep inertia depends on operational characteristics. Infantry personnel generally have a long enough period after waking to shake off sleep inertia, particularly if they use the simple effective means suggested by Labuc (45, 46, 47) for removing sleep inertia. In contrast, C2 personnel, dozing in their workplace, might be awakened and required to work immediately while still in a state of sleep inertia.

DCIEM experiments found similar degrees of sleep inertia occurred after a midnight nap as following an early morning nap, evidence against sleep inertia being circadian controlled. EEG observations (see Figure 6)

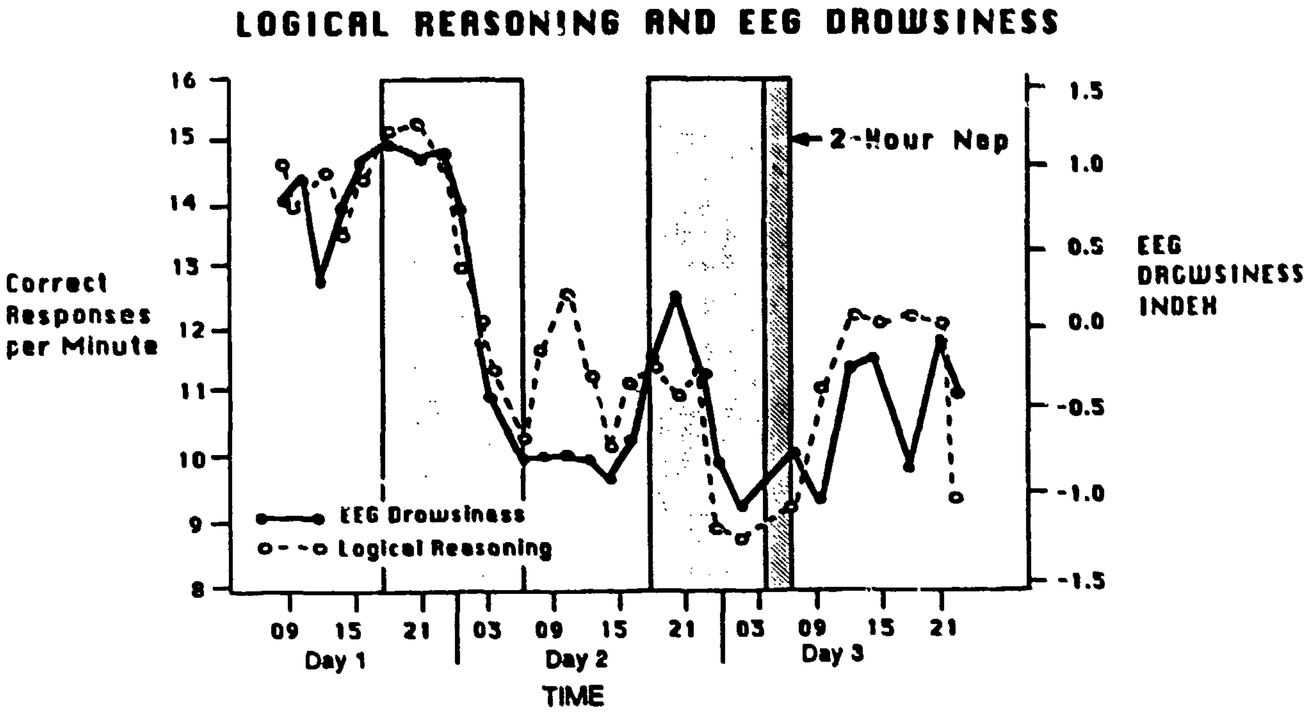

Figure 6: Logical Reasoning task results plotted against an index of EEG drowsiness. Data for the EEG drowsiness index were collected during 4-minute eyes closed relaxation periods given every hour during the waking portions of the experiment.

The index calculated as follows: period analysis was used to quantify (bipolar C3-01) EEG recorded during each 4-minute period. Each period was divided into twenty-four 10-second epochs on which power estimates were calculated for delta (.5-4 Hz), theta (4-8 Hz), alpha (8-12 Hz), sigma (12-16 Hz), and beta (16-40 Hz). For each 4 minute period mean values were obtained for each bandwidth by collapsing across the 24 epochs. A drowsiness index was calculated as follows: $(AP-TP-DP)/(AP_b-TP_b-DP_b)$ where AP, TP and DP are mean alpha, theta and delta power. Baseline values were calculated by averaging the EEG for each bandwidth for the first four relaxation periods in the experiment when the subjects were fresh and produced maximal alpha. It can be seen from the above equation that subjects who are very low alpha generators may yield a negative denominator and thus produce a different scale. For these individuals a corrected equation is used: $(AP-TP-DP)/(AP_b-TP_b-DP_b)\ x{-1} + 2$. Values from the resulting drowsiness scale will vary from approximately 1 to a larger minus number, depending upon the depth of slow wave sleep (see Pigeau, Heslegrave and Angus, in press).

revealed that the periods of sleep inertia were characterized by stage 1-like EEGs (see also Pigeau, Heslegrave and Angus (71)).

3.2 Naval Health Research Center NHRC Research

Background

Morgan and Coates (59) raised the question of whether performance was influenced by the starting time (morning, afternoon, or late evening) of sustained operations (SUSOPS). Their subjects started prolonged work periods at 0600h, 1400h, or 2200h. Performance remained near 100% of the baseline level for 35 hours if the continuous work episode started at 1400h. Performance declined significantly when the work period started at 0600h, particularly during 0400h-0800h, presumably due to interaction of the circadian low with prolonged time on the job. Performance deteriorated precipitously starting at 2000h of the second day in the group starting at 2200h, with the lowest level of performance between 0400h-0600h. These findings are important for military planners since military missions can involve continuous work periods starting at any time of day.

Experimental Environment

The NHRC laboratory is contained in a barracks and can accommodate two subjects. It has an EEG, ECG, and other physiological equipment in addition to a treadmill to allow walking at various speeds and grades. The protocols provide continuous high physical and cognitive demands. They simulate a U. S. Marine Corps reconnaissance operation, where the primary purpose is to walk stealthily through rugged terrain, searching, locating, and destroying enemy sites. Each Marine carries limited supplies on his person. A realistic account of Force Reconnaissance Units is given by F. J. West (90, pp. 63-73).

Experimental Design and Tasks

During the 1979-1986 period, NHRC conducted a series of seven 5 day SUSOPS studies. In studies 1, 5, and 6, listed in Tables 1 and 2, they attempted to replicate the findings of Morgan and Coates and to investigate the effects of exercise and circadian nap timing. In study 1 subjects took a 3 hour morning nap (0400h to 0700h); in study 5, a 3 hour midnight nap (2000h to 2300h); and, in study 6 a 3 hour noon nap (0900h to 1200h).

TABLE 1. EXPERIMENTAL VARIABLES

			MISSION STARTUP TIME		
		Exercise (E)* Control (C)	08 AM	Noon	Midnight
LENGTH OF NAP	0 hr	E (30%) E (40%) C C	STUDY 2 STUDY 4 STUDY 2 STUDY 4	XX	XX
	3 hrs	E (30%) C	STUDY 1 STUDY 1	STUDY 6 STUDY 6	STUDY 6 STUDY 6
	4 hrs	E (40%) C	STUDY 3 STUDY 3	XX	XX
	8 hrs	C	STUDY 7	XX	XX

* = Physical workload set to be at % MAX O_2.
XX = No study corresponding to this cell was conducted due to time constraint.
This chapter is concerned with the data from Studies 1, 5 and 6.

TABLE 2. DATA COLLECTION SCHEDULE

	Orientation	Adaptation Sleep	Baseline Work	Baseline Sleep	CW1	NAP	CW2	Recovery
Study 1 = Morning	(08-22)*	(23-07)	(08-22)*	(23-07)*	(08-03)*	(04-07)*	(08-03)*	(04-12)
Study 6 = Noon	(08-12)*		(13-03)*	(04-12)*	(13-08)*	(09-12)	(13-08)*	(11-19)
Study 5 = Midnight	(08-19)*	(20-04)*	(05-14)*	(15-23)*	(00-19)*	(20-23)*	(00-19)*	(20-04)

* Time needed to go from one phase to the next phase

On Day 1 of study 1 (morning nap) the volunteer Marines were given exercise tests to determine maximal oxygen consumption (VO_2max). During the remainder of Day 1, the subjects were trained in taking a psychological assessment battery developed at NHRC (NHRC-PAB). This includes various tests sensitive to sleep loss and fatigue: (1) a simple, unprepared reaction time task modeled after Lisper and Kjellberg (51); (2) an alpha-numeric visual vigilance task; (3) a four-choice serial reaction time task as described by Wilkinson and Houghton (96); (4) a logical reasoning task (7); (5) an auditory word memory test (99, 2); And (6) a key-tapping task as described in Friedmann et al. (22). NHRC-PAB also measures subjective ratings of moods, fatigue, and physical exertion with NHRC Mood Questionnaire (42), the School of Aerospace Medicine (SAM) subjective fatigue checklist (29), and Rating of Perceived Exertion (11).

Baseline data was collected on Day 2, and the experiment began at 0800h on Day 3. One member of each pair of subjects was randomly assigned to an exercise group and the other to a non-exercise group. During the first half hour of each hourly session, the exercise subjects performed the visual vigilance task while walking on the treadmill at a speed which kept oxygen consumption at about 30% of VO_2max. Non-exercise subjects performed the same visual vigilance test while seated in front of a CRT monitor.

The first 20 hour continuous work episode (CW1) ended at 0400h of day 4, when a 3 hour nap was allowed. Subjects were awakened at 0700, given breakfast, and started on the second 20 hour continuous work period (CW2) at 0800. CW2 ended at 0300h of day 5. Subjects were given dinner and then allowed to sleep for 8 hours (0400-1200h). The top line of Table 2 shows the data collection schedule.

The data collection protocol of study 5 (midnight nap) was identical to study 1, except that the work schedule was shifted to start at midnight (see the third line of Table 2). The data collection protocol for study 6 was also similar (see second line of Table 2). Here the schedule was shifted to start at 1300h by having the subjects work continuously from early morning day 1 until 0300h day 2, followed by an 8 hour sleep (0400h-1200h).

Experimental Results

Table 3 shows the results of studies 1, 5 and 6. Exercising dramatically increased the degrading effects of 20 hours of prolonged work. Looking at the 10% slowest simple unprepared reaction times in each session, there

TABLE 3. RELATIVE RECUPEERATIVE POWER OF NAP IN THREE GROUPS OF "EXERCISE" SUBJECTS

	Early Morning Nap			Noon Nap			Midnight Nap		
	Pre	Post		Pre	Post		Pre	Post	
		Proximal	Distal		Proximal	Distal		Proximal	Distal
Simple Reaction Time in msec (10% Slow)	817 (417)	1036 (674)	1136 (589)	1545 (695)	1038 (617)	1521 (848)	685 (673)	832 (596)	1071 (765)
Four Choice Response in msec (10% Slow)	1487 (450)	1540 (404)	1568 (483)	2049 (505)	1704 (513)	2224 (499)	1417 (422)	1502 (206)	1766 (496)
Tapping Response in msec (10% Slow)	777 (330)	914 (332)	854 (458)	939 (375)	804 (182)	831 (343)	854 (380)	790 (335)	877 (396)
Four Choice (% Correct)	82.6 (20.3)	85.3 (19.8)	77.8 (26.6)	58.4 (17.9)	78.2 (21.6)	48.2 (24.9)	87.7 (18.8)	90.7 (12.3)	75.4 (28.1)
Visual Vigilance (% Correct)	78.7 (16.7)	77.1 (21.0)	68.6 (25.9)	77.8 (20.0)	85.9 (13.0)	76.7 (22.9)	92.4 (5.6)	88.2 (16.1)	88.9 (14.9)
Logical Reasoning (% Correct)	87.6 (11.2)	92.0 (4.9)	89.9 (9.3)	71.8 (26.8)	85.4 (19.1)	75.0 (17.5)	89.7 (12.0)	92.9 (9.5)	93.1 (8.6)
Word Memory (% Correct Recall)	49.7 (11.2)	45.8 (20.9)	63.0 (11.9)	53.3 (16.9)	56.5 (22.8)	53.3 (18.8)	53.1 (18.8)	57.1 (21.1)	53.9 (19.8)
NHRC Mood (Negative)	6.0 (3.9)	6.1 (5.0)	7.2 (5.7)	12.7 (7.0)	4.9 (5.4)	12.0 (6.4)	6.4 (5.3)	7.5 (8.1)	6.7 (4.4)
SAM Fatigue Checklist	9.6 (4.3)	8.7 (4.0)	8.5 (5.7)	12.6 (5.8)	9.0 (4.3)	13.8 (3.3)	10.6 (4.4)	9.5 (3.2)	11.7 (5.9)
Borg's RPE	10.8 (1.6)	10.6 (2.2)	[illegible] (2.1)	12.6 (3.1)	10.0 (2.1)	12.8 (2.6)	11.1 (2.4)	10.4 (4.0)	11.6 (3.0)

Pre = Average and SD of data taken 1 to 5 hours before nap during the first continuous work day.
Post (Proximal) = Average and SD of data taken 1 to 4 hours after nap.
Post (Distal) = Average and SD of data taken 15-19 hours after nap.

were no between nap group differences during the early sessions of CW2, suggesting that all naps were beneficial. However, during the last 4 sessions of CW2, the reaction times of the noon nap group slowed much more than those of the other groups. Similar results were found for the 10% slowest reaction times and the percent correct responses in the Four-Choice task. In contrast, the morning group got a lower percent correct detection in comparison with the noon and midnight nap groups on the alpha-numeric, visual vigilance task. They also showed the lowest percent-correct recall in the word memory test during CW2.

The NHRC positive mood scale results, tapping task performance, and ratings of perceived exertion during exercise were not affected by the time of napping. However, the subjects in the noon group had the greatest increase in the NHRC negative scale scores near the end of CW2 and the highest SAM fatigue scale scores near the end of both CW1 and CW2.

In general, all nap times showed similar benefit soon after the first night of sleep deprivation, but the noon nap group showed more deterioration of mood and performance toward the end of the second day, even though the results of sleep stage analysis showed that the subjects in the noon group slept normally and had sleep efficiency similar to the other groups. The last periods of CW1 and CW2 for the noon group fell during the circadian trough period (0400h- 0700h). As noted, this group had higher SAM fatigue scores even at the end of CW1 <u>before</u> the nap, indicating there were effects from the jet lag like shift in their work schedule. This group's degradation in task performance at the end of CW2 may be secondary to direct circadian effects or to an interaction of these effects with time-on-the-job and circadian timing of the nap.

4.0 CONCLUSION: IMPLICATIONS AND FUTURE NEEDED RESEARCH

We have reviewed studies which have shown that subjects (regardless of their usual sleep duration) need 4 to 5 hours of sleep per night to maintain performance level. Naps taken during prolonged work periods can prevent or reduce sleep decrements in mood and performance and can recuperate subjects from such decrements after they have occurred. The length of nap required depends on the duration of sleep loss involved and type of task to be done.

Shortening sleep periods can reduce sleep efficiency and change the proportions of various sleep stages. Fragmentation of nocturnal sleep can produce behavior impairment. However, subjects can adapt to markedly abnormal sleep/wake cycles, and 4 to 10 minute durations of sleep periods appear to be sufficient for maintaining a fairly normal sleep stage distribution. Sleep fragmented into two 2 hour naps has sometimes been found as beneficial as one 4 hour nap.

In prolonged military operations, opportunities for uninterrupted sleep do not exist. The only alternative to napping is prolonged wakefulness. Polyphasic sleep, with frequent naps rather than a single sleep period per 24 hours, is natural for both the very young and for the aged. It is not practiced by most adults, perhaps because of societal demands. Possibly a polyphasic sleep schedule could be developed which would reduce circadian troughs in performance and mood during prolonged work periods.

One minute nocturnal naps do not refresh subjects, even though they sleep 4.5 hours per night. Performance following two nights of such ultrashort sleep is no better than with no sleep at all. The duration of ultrashort sleep required for recuperative effects needs to be determined. Such study may help elucidate the endocrinological and physiological factors involved in the recuperative effects of sleep. Research on ultrashort sleep currently is being conducted by Broughton in collaboration with Stampi. We are planning laboratory-based studies on ultrashort sleep to determine how short sleep can be before it ceases to be beneficial, and how efficient ultrashort sleep is in maintaining reviving performance.

We have warned that napping is a double-edged sword; its beneficial effects must be balanced against the negative effects of sleep inertia. DCIEM studies documented significant sleep inertia effects on performance shortly after awakening from both noon and early morning naps. These effects are transient but can be important in some operational situations. For example, if sleep inertia of 10 minutes or longer is expected to occur, then fighter pilots must not be allowed to doze off in the cockpit of a jet below a carrier deck during yellow alert states while awaiting a possible red alert.

Sleep inertia was previously vaguely defined as a lowered psychological state following sudden awakening. DCIEM EEG data suggests that sleep inertia resembles stage 1 sleep, that subjects look awake, but physiologically are not fully awake. These studies indicate the value of polygraphic monitoring of subjects throughout behavioral sessions.

It is impossible to be certain from current knowledge, including the DCIEM and NHRC studies, whether there is a time-of-day influence on the beneficial effects of naps. Is it always true that "some sleep is better than no sleep at all" and "the longer the sleep the greater the increase in alertness" (32, 34)? Results have been inconsistent, possibly because of interaction with or masking from direct circadian effects on performance or on sleep inertia. Sleep inertia severity might relate to many factors including prior hours of wakefulness, duration of nap, and the time-of-day the nap is taken. The effects of exercise are also unclear. The NHRC studies found that including exercise in the prolonged work periods increased performance deterioration, while studies at DCIEM found no exercise effects.

So, performance under prolonged work demands may be affected by many factors in addition to sleep loss including the factors discussed by Webb (84) (see section 2) as well as boredom, sleep stages, sleep inertia, and physical exertion. Because of these possible complex interactions more data are required before a behavioral model can be developed to predict the utility of napping. Currently all these factors must be considered when designing schedules for improving performance through napping strategies. However, if the studies' results can be confirmed which have suggested that specific proportions of sleep stage activity are not needed to guarantee recuperative effects, and that there is no circadian component to sleep inertia or to the recuperative effects of naps, sleep management would be much simpler.

REFERENCES

1. Ainsworth, L.L., and Bishop, H.P. (1971): The Effects of a 48-Hour Period of Sustained Field Activity on Tank Crew Performance. HumRRO Technical Rep 71-16, Alexandria, VA.
2. Akerstedt, T. and Gillberg, M. (1979): Effects of sleep deprivation on memory and sleep latencies in connection with repeated awakenings from sleep. Psychophysiology, 16:49-52.
3. Alluisi, E.A. (1969): Sustained performance. In: Principles of Skill Acquisition, edited by E.A. Bilodeau and I.M. Bilodeau, pp. 59-101. New York, Academic Press.
4. Angus, R.G. and Heslegrave, R.J. (1983): The effects of sleep loss and sustained mental work: Implications for command and control performance. In: AGARD Conference Proceedings No. 338 Sustained Intensive Air Operations: Physiological and Performance Aspects. NATO, Paris.
5. Angus, R.G. and Heslegrave, R.J. (1985): Effects of sleep loss on sustained cognitive performance during a command and control simulation. Behav. Res. Meth. Instru. Comp., 17:55-67.
6. Angus, R.G., Heslegrave, R.J., and Myles, W.S. (1985): Effects of prolonged sleep deprivation, with and without chronic physical exercise, on mood and performance. Psychophysiology, 22:276-282.
7. Baddeley, A.D. (1968): A 3 min reasoning test based on grammatical transformation. Psychonom. Sci., 10:341-342.
8. Bonnet, M.H. (1983): Memory for events occurring during arousal from sleep. Psychophysiology, 20:81-87.
9. Bonnet, M.H. (1985): Effect of sleep deprivation on sleep, performance and mood. Sleep, 8:11-19.
10. Bonnet, M.H. (1986): Performance and sleepiness as a function of frequency and placement of sleep disruption. Psychophysiology, 23:263-271.
11. Borg, G. (1985): An Introduction to Borg's RPE-Scale. Mouvement Publications, Ithaca, New York.
12. Broughton, R.J. and Mamelack, M. (1980): Effects of gamma-hydroxy butyrate on sleep/wake patterns in narcolepsy-cataplexy. Can. J. Neurol. Sci., 7:23-31.

13. Carskadon, M.A. and Dement, W.C. (1975): Sleep studies on a 90 minute day. EEG Clin. Neurophysiol., 39:145-155.

14. Carskadon, M.A. and Dement, W.C. (1977): Sleepiness and sleep state on a 90-minute schedule. Psychophysiology, 14:127-133.

15. Cook, M.R., Cohen, H., and Orne, M.T. (1972): Recovery from fatigue. Technical Report No. 55. U.S. Army Medical Research and Development Command, Fort Detrick, MD.

16. Dinges, D.F., Orne, E.C., Evans, F.J., and Orne, M.T. (1981): Performance after naps in sleep-conducive and alerting environments. In: Biological Rhythms, Sleep and Shift Work: Advances in Sleep Research, Vol. 7, edited by L.C. Johnson, D.I. Tepas, W.P. Colquhoun, and M.J. Colligan, pp. 539-552. Spectrum, New York.

17. Dinges, D.F., Orne, M.T., and Orne, E.C. (1985): Assessing performance upon abrupt awakening from naps during quasi-continuous operations. Behav. Res. Methods Instru. Computers, 17:37-45.

18. Dinges, D.F., Whitehouse, W.G., Orne, E.C., and Orne, M.T. (In press): The benefits of a nap during prolonged wakefulness.

19. Drucker, E.H., Cannon, L.D., and Ware, J.R. (1969): The Effects of Sleep Deprivation on Performance over a 48-hour Period. HumRRO Technical Rep 69-8, Alexandria, VA.

20. Feltin, M. and Broughton, R. (1968): Differential effects of arousal from slow wave versus REM sleep. Psychophysiology, 5:231.

21. Fort, A. and Mills, J.N. (1972): Influence of sleep, lack of sleep and circadian rhythm on short psychometric tests. In: Aspects of Human Efficiency, edited by W.P. Colquhoun, pp. 115-128. The English Universities Press, London.

22. Friedmann, J., Globus, G., Huntley, A.B., Mullaney, D., Naitoh, P., and Johnson, L.C. (1977): Performance and mood during and after gradual sleep reduction. Psychophysiology, 14:245-250.

23. Gillberg, M. (1984): The effects of two alternative timings of one-hour nap on early morning performance. Biol. Psychol., 19:45-54.

24. Gillberg, M. (1985): Effects of naps on performance. In: Hours of Work, edited by S. Folkard and T. Monk, pp. 77-86. Wiley, New York.

25. Gillberg, M. and Akerstedt, T. (1982): Effect of 1-hour nap on performance following restricted sleep. In: Sleep 1982 European Congress on Sleep Research, Zurich, 1982, pp. 392-394. Karger, Basel.

26. Guilleminault, C. and Dement, W.C. (1978): Sleep apnea syndromes and related sleep disorders. In: Sleep Disorders: Diagnosis and Treatment, Wiley, New York.

27. Hamilton, P., Wilkinson, R.T., and Edwards, R.S. (1972): A study of four days partial sleep deprivation. In: Aspects of Human Efficiency, edited by W.P. Calquhoun, pp. 101-113. The English Universities Press, London.

28. Hartley, L.R. (1974): A comparison of continuous and distributed reduced sleep schedules. Quart. J. Exp. Psychol., 26:8-14.

29. Harris, D.A., Pegram, G.V., and Hartman, B.O. (1971): Performance and fatigue in experimental double-crew transport missions. Aviat. Space Env. Med., 24:980-986.

30. Harris, W. and O'Hanlon, J.F. (1972): A Study of Recovery Function in Man. U. S. Army Engineering Laboratories, Aberdeen Proving Ground Tech Memo No. 10-72. Aberdeen Proving Ground, Maryland.

31. Haslam, D.R. (1981): The military performance of soldiers in continuous operations: Exercise early call I and II. In: Biological Rhythms, Sleep and Shift Work, edited by L.C. Johnson, W.P. Tepas, W.P. Colquhoun and M.J. Colligan, pp. 435-458. Spectrum, New York.

32. Haslam, D.R. (1982): Sleep loss, recovery sleep, and military performance. Ergonomics, 25:163-178.

33. Haslam, D.R. (1984): The military performance of soldiers in sustained operations. Avia. Space Environ. Med., 55:216-221.

34. Haslam, D.R. (1985): Sleep deprivation and naps. Behav. Res. Methods Instru. Computers, 17:46-54.

35. Heslegrave, R.J. and Angus, R.G. (1983): Sleep loss and continuous cognitive work. In: Proceedings of the 24th Defence Research Group (NATO) Seminar on the Human as a Limiting Element in Military Systems. Vol. 1, pp. 61-108.

36. Heslegrave, R.G., and Angus, R.G. (1985): The effects of task duration and work-session location on performance degradation induced by sleep loss and sustained cognitive work. Behav. Res. Methods Instru. & Computers, 17:592-603.

37. Hoddes, E., Zaarcone, V., Smythe, H., Phillips, R. and Dement, W.C. (1973): Quantification of sleepiness: A new approach. Psychophysiology, 10:431-436.

38. Horne, J.A. (1978): A review of the biological effects of total sleep deprivation in man. Biol. Psychol., 7:55-102.

39. Horne, J.A. and Minard, A. (1985): Sleep and sleepiness following a behaviorally "active" day. Ergonomics, 28:565-575.

40. Johnson, L.C. (1979): Sleep disturbances and performance. In: Sleep, Wakefulness and Circadian Rhythm (NATO AGARD Lecture Series No. 105), edited by A.N. Nicholson, pp. 8:1-8:17. AGARD, Paris.

41. Johnson, L.C. (1982): Sleep deprivation and performance. In: Bilogical Rhythms, Sleep and Performance, edited by W.B. Webb, pp. 111-141. Wiley, Chichester, England.

42. Johnson, L.C. and Naitoh, P. (1974): The Operational Consequences of Sleep Deprivation and Sleep Dificit. NATO Advisory Group for Aerospace Research and Development (AGARD), Paris.

43. Johnson, L.C., Naitoh, P., Moses, J.M. and Lubin, A. (1974): Interaction of REM deprivation and stage 4 deprivation with total sleep loss: Experiment 2. Psychophysiology, 11:147-159.

44. Laird, D.A. and Muller, C.G. (1930): Sleep, Why We Need It and How to Get More of It. The John Day Company, New York.

45. Labuc, S. (1978a): A Study of Performance Upon Sudden Awakening. Report APRE No. 1/78. Army Personnel Research Establishment.

46. Labuc, S. (1978b): Performance Upon Awakening from Four Hours Sleep per Night. Report APRE No. 7/78. Army Personnel Research Establishment.

47. Labuc, S. (1978c): The Effect of a One Minute Alerting Procedure on Performance after Sudden Awakening from Sleep. Army Personnel Research Establishment.

48. Langdon, D.E., and Hartman, B. (1961): Performance upon sudden awakening. USAF School of Aerospace Medicine, SAM Rep 62-17. Brooks AFB, Texas.

49. Lavie, P. and Scherason, A. (1981): Ultrashort sleep-waking schedules. I. Evidence of ultradian rhythmicity in 'sleepability.' EEG Clin Neurophysiol., 52:163-174.

50. Lavie, P. and Veler, B. (In press): Timing of naps: Effects on post nap sleepiness levels. Work and Stress.

51. Lisper, H. and Kjellberg, A. (1972): Effects of a 24-hour sleep deprivation on rate of decrement in a 10-minute auditory reaction time task. J. Exp. Psychol., 96:287-290.

52. Lubin, A., Hord, D.J., Tracy, M.L., and Johnson, L.C. (1976): Effects of exercise, bedrest, and napping on performance decrement during 40 hours. Psychophysiology, 13:334-339.

53. Lubin, A., Moses, J.M., Johnson, L.C., and Naitoh, P. (1974): The recuperative effects of REM sleep and stage 4 sleep. Experiment I. Psychophysiology, 11:133-146.

54. Lugaresi, E., Coccagna, G., Gambi, D., Barti-Ceroni, G., and Foppi, M. (1966): A propos de quelques manifestations nocturnes myocloniques, (Nocturnal myoclonus of Symonds). Rev. Neurol. (Paris), 115:547-555.

55. MaGee, J., Harsh, J., and Badia, P. (In press): Effects of experimentally-induced sleep fragmentations on sleep and sleepiness. Psychophysiology.

56. Moore-Ede, M.C., Sulzman, F.M., and Fuller, C.A. (1982): The human circadian timing system. In: The Clocks That Time Us, (Chapter 6), authored by M.C. Moore-Ede, F.M. Sulzman, and C.A. Fuller, pp. 295-317.

57. Morgan, B.B., Coates, G.D., Brown, B.R., and Alluisi, E.A. (1973): Effects of Continuous work and sleep loss on the recovery of sustained performance. U.S. Army Technical Memo 14-73, Human Engineering Lab., Aberdeen Proving Ground, Maryland.

58. Morgan, B.B., Brown, B.R., and Alluisi, E.A. (1974): Effects of sustained performance of 48 hours of continuous work and sleep loss. Human Factors, 16:406-414.

59. Morgan, B.B. and Coates, C.D. (1974): Sustained performance and recovery during Continuous Operations. Interim Technical Rep. ITR-74-2. Old Dominion University, Norfolk, VA.

60. Moses, J.M., Hord, D.J., Lubin, A., Johnson, L.C. and Naitoh, P. (1975): Dynamics of nap sleep during a 40 hour period. EEG Clin. Neurophysiol. 39:627-633.

61. Montplaisir, J. (1976): Disturbed nocturnal sleep. In: Narcolepsy, edited by C. Guilleminault, W.C. Dement, and P. Pasouant, pp. 43-56. Spectrum, New York.

62. Mullaney, D.J., Kripke, D.F., Fleck, P.A., and Johnson, L.C. (1983): Sleep loss and nap effects on sustained continuous performance. Psychophysiology, 20:643-651.

63. Naitoh, P. (1969): Sleep Loss and Its Effects on Performance. U.S. Navy Medical Neuropsychiatric Research Unit Technical Rep. 68-3. U.S. Navy Medical Neuropsychiatric Research Unit, San Diego.

64. Naitoh, P. (1976): Sleep deprivation in human subjects: A reappraisal. Waking and Sleeping, 1, 53-60.

65. Naitoh, P., Johnson, L.C., and Lubin, A. (1973): The effect of selective and total sleep loss on the CNV and its psychological and physiological correlates. In: Event-related Slow Potential of the Brain: Their Relations to Behavior, edited by W.C. McCallum and J.R. Knott, pp. 213-218. Elsevier, Amsterdam.

66. Naitoh, P. (1981): Circadian cycles and restorative power of naps. In: Biological Rhythms, Sleep and Shiftwork: Advances in Sleep Research, Vol. 7, pp. 553-580. Spectrum, New York.

67. Naitoh, P., Englund, C., and Ryman, D. (1982): Restorative power of naps in designing continuous work schedules. Naval Health Research Center Technical Rep 82-25. Naval Health Research Center, San Diego.

68. Naitoh, P., Englund, C.E., and Ryman, D.H. (1986): Sleep Management in Sustained Operations: User's Guide. Naval Health Research Center Tech Rep 86-22. Naval Health Research Center, San Diego.

69. Nicholson, A.N., Pascoe, P.A., Roehrs, T. (1985): Sustained performance with short evening and morning sleeps. Avia. Space Environ. Med., 56:105-114.

70. Opstad, P.K., Ekanger, R., Nummestad, M., and Raabe, N. (1978): Performance, mood, and clinical symptoms in men exposed to prolonged, severe physical work and sleep deprivation. Avia. Space Environ. Med., 49:1065-1073.

71. Pigeau, R.A., Heslegrave, R.J., and Angus, R.G. (In press): Psychophysiological measures of drowsiness as estimates of mental fatigue and performance degradation during sleep deprivation. In: Electric and Magnetic Activity of the Central Nervous System. Research and Clinical Applications in Aerospace Medicine, NATO AGARD, Paris.

72. Rosa, R.R., Bonnet, M.H., and Warm, J.S. (1983): Recovery of performance during sleep following sleep deprivation. Psychophysiology, 20:152-159.

73. Rutenfranz, J., Aschoff, J., and Mann, H. (1972): The effects of a cumulative sleep deficit, duration of preceding sleep period and body-temperature on multiple choice reaction time. In: Aspects of Human Efficiency, edited by P. Colquhoun, pp. 217-230. The English Universities Press, London.

74. Scott, J. (1969): Performance after abrupt arousal from sleep: Comparison of a simple motor, a visual-perceptual, and a cognitive task. In: Proceedings of 77th Annual Convention of American Psychology Association, pp. 225-226.

75. Scott, J., and Snyder, F. (1968): 'Critical Reactivity' (Pieron) after abrupt awakenings in relation to EEG stages of sleep. Psychophysiology, 4:370.

76. Smith, M. (1916): A contribution to the study of fatigue. Brit. J. Psychol., 8:327-350.

77. Seidel, W.F., Roth, T., Roehrs, T., Zorick, F., and Dement, W.C. (1984): Treatment of a 12-hour shift of sleep schedule with benzodiazepines. Science, 224:1262-1264.

78. Stampi, C. (1985a): Ultrashort sleep-wake cycles improve performance during one-man transatlantic races. In: Sleep '84, edited by W.P Koella, E. Ruther and H. Schutz, pp. 271-272. Gustav Fisher, Stuttgart.

79. Stampi, C. (1985b): Ultrashort sleep-wake cycles during single-handed transatlantic races. In: Circadian Rhythms in the Central Nervous System, edited by P.H.Redfern, I.C. Campbell, J.A. Davis, and K.F. Martin, pp. 229-232. VCH (Macmillan), Basingstoke, England.

80. Taub, J.M. (1979): Effects of habitual variations in napping on psychomotor performance, memory and subjective states. Intern. J. Neurosci., 9:97-112.

81. Taub, J.M., and Berger, R.J. (1973): Performance and mood following variations in the length and timing of sleep. Psychophysiology, 10:559-570.

82. Taub, J.M., Tanguay, P.E., and Clarkson, D. (1976): Effects of daytime naps on performance and mood in a college student population. J. Abnor. Psychol., 85:210-217.

83. Tilley, A.T., and Wilkinson, R.T. (1984): The effects of a restricted sleep regime on the composition of sleep and on performance. Psychophysiology, 21:406-412.

84. Webb, W.B. (1985): Experiments on extended performance: Repetition, age, and limited sleep periods. Behav. Res. Methods Instru. Computers, 17:27-36.

85. Webb, W.B. (In press): The proximal effects of two and four hour naps within extended performance without sleep. Psychophysiology.

86. Webb, W.B., and Agnew, H.R., Jr., (1964): Reaction time and serial response efficiency on arousal from sleep. Percept. Motor Skills, 18:783-784.

87. Webb, W.B., and Agnew, H.W., Jr., (1965): Effects of a restricted sleep regime. Science, 150:1745-1747.

88. Webb, W.B., and Agnew, H.W. (1974): The effects of a chronic limitation of sleep length. Psychophysiology, 11:265-274.

89. Weitzman, E., Nogeire, C., Perlow, M., Fukushima, D., Sassin, J., McGregor, P., Gallagher, T., and Hellman, L. (1974): Effects of a prolonged 3-hour sleep wakefulness cycle on sleep stages, plasma cortisol, growth hormone and body temperature in man. J. Clin. Endocrinol. Metab., 38:1018-1030.

90. West, F.G. (1967): The Indians. In: Small Unit Action in Vietnam Summer 1966, authored by F.J. West, pp. 59-67. History and Museums Division, Headquarters, U.S. Marine Corps, Washington, D.C.

91. Wilkinson, R.T. (1961): Interaction of lack of sleep with knowledge of results, repeated testing and individual differences. J. Exp. Psychol., 62:263-271.

92. Wilkinson, R.T. (1965): Sleep deprivation. In: The Physiology of Human Survival, edited by O.G. Edholm, and A.L. Bachrach, pp. 399-430. Academic Press, New York.

93. Wilkinson, R.T. (1969): Sleep deprivation: Performance tests for partial and selective sleep deprivation. In: Progress in Clinical Psychology, edited by L.A. Abt and B.F. Riess, pp. 28-43. Gruen and Stratton, New York.

94. Wilkinson, R.T. (1972): Sleep deprivation - eight questions. In: Aspects of Human Efficiency, edited by P. Colquhoun, pp. 25-30. The English Universities Press, London.

95. Wilkinson, R.T., Edwards, R.S., and Haines, E. (1966): Performance following a night of reduced sleep. Psychon. Sci., 5:471-472.

96. Wilkinson, R.T., and Houghton, D. (1975): Portable four-choice reaction time test with magnetic tape memory. Behav. Res. Methods Instru Computers, 7:441-446.

97. Wilkinson, R.T., and Stretton, M. (1971): Performance after awakening at different times of night. Psychon. Sci., 23:283-285.

98. Williams, H.L., Lubin, A., and Goodnow, J.J. (1959): Impaired performance with acute sleep loss. Psychol. Monogr., 73(14).

99. Williams, H.L., Gieseking, C.F., and Lubin, A. (1966): Some effects of sleep loss on memory. Percept Motor Skills, 23:1287-1293.

100. Woodward, D., and Nelson, P.D. (1974): A User Oriented Review of the Literature on the Effects of Sleep Loss, Work-Rest Schedules, and Recovery on Performance. Office of Naval Research, Arlington, VA.

Unclassified
SECURITY CLASSIFICATION OF THIS PAGE

A190 228

REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION
Unclassified

1b. RESTRICTIVE MARKINGS
None

2a. SECURITY CLASSIFICATION AUTHORITY
N/A

2b. DECLASSIFICATION / DOWNGRADING SCHEDULE
N/A

3. DISTRIBUTION / AVAILABILITY OF REPORT
Approved for public release; distribution unlimited.

4. PERFORMING ORGANIZATION REPORT NUMBER(S)
NHRC Report No. 87-21

5. MONITORING ORGANIZATION REPORT NUMBER(S)

6a. NAME OF PERFORMING ORGANIZATION
Naval Health Research Center

6b. OFFICE SYMBOL (If applicable)
60

7a. NAME OF MONITORING ORGANIZATION
Commander, Naval Medical Command

6c. ADDRESS (City, State, and ZIP Code)
P.O. Box 85122
San Diego, CA 92138-9174

7b. ADDRESS (City, State, and ZIP Code)
Department of the Navy
Washington, D.C. 20372

8a. NAME OF FUNDING / SPONSORING ORGANIZATION Naval Medical Research & Development Command

8b. OFFICE SYMBOL (If applicable)

9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER

8c. ADDRESS (City, State, and ZIP Code)
Naval Medical Command National Capitol Regio
Bethesda, MD 20814-5044

10. SOURCE OF FUNDING NUMBERS

PROGRAM ELEMENT NO.	PROJECT NO.	TASK NO.	WORK UNIT ACCESSION NO.
63764A	3M463764 B995	AB.087	DA307899

11. TITLE (Include Security Classification)
(U) NAPPING AND HUMAN FUNCTIONING DURING PROLONGED WORK

12. PERSONAL AUTHOR(S)
NAITOH, Paul, ANGUS, Robert G.

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15. PAGE COUNT
Interim	FROM ____ TO ____	1987April30	38

16. SUPPLEMENTARY NOTATION Prepared in cooperation with Robert G. Angus, Defence and Civil Institute of Environmental Medicine, Canada under TTCP, Subgroup U, Technical Panel 4 auspices.

17. COSATI CODES

FIELD	GROUP	SUB-GROUP

18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
Nap, Mood, Sleep management, Performance, Sleep deprivation, Ultra-short sleep, Prolonged work, Sleep inertia.

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

In prolonged work periods, men and women often forego satisfying their sleep need to complete their assigned jobs, resulting in an accumulation of performance/mood degrading sleep loss and fatigue. Sleep need can be satisfied only by a slow process of sleeping for an average of 7 to 8 consecutive hours per 24 hour period, i.e., a long period of "time-out." However, sleep management suggests that recovery from fatigue and sleepiness during a prolonged work period can be accomplished by short or ultra-short sleep (naps) taken during a prolonged work period. Naps are shown not only to refresh and restore human functioning, but also to maintain performance and mood during a prolonged work period. In this paper, naps' power as a counter-degradation measure are described first through the literature review, and then through critical evaluation of studies conducted at the Defence and Civil Institute of Environmental Medicine, Canada and the Naval Health Research Center. The need for research and recommendation about ultra-short naps is discussed in the context of refining sleep management techniques applied in the field work environments. Keywords:

20. DISTRIBUTION / AVAILABILITY OF ABSTRACT
☐ UNCLASSIFIED/UNLIMITED ☒ SAME AS RPT. ☐ DTIC USERS

21. ABSTRACT SECURITY CLASSIFICATION
Unclassified

22a. NAME OF RESPONSIBLE INDIVIDUAL
Paul Naitoh

22b. TELEPHONE (Include Area Code)
(619) 225-7393

22c. OFFICE SYMBOL
60

DD FORM 1473, 84 MAR — 83 APR edition may be used until exhausted. All other editions are obsolete

SECURITY CLASSIFICATION OF THIS PAGE